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Aortic arch repair for Stanford type A aortic dissection with distal anastomosis to the proximal level of the distal aortic arch

Yoshio Mori, MD, PhD
Hajime Hirose, MD, PhD
Hisato Takagi, MD, PhD
Yukio Umeda, MD, PhD
Yukiomi Fukumoto, MD, PhD
Katsuya Shimabukuro, MD
Yukihiro Matsuno, MD

Background: In acute type A dissection, replacing the ascending aorta with the transverse aortic arch recently has been recommended for event-free long-term survival. Since 1994, we have performed our new transverse aortic arch replacement, in which the distal end of the graft is anastomosed between the left common carotid artery and the left subclavian artery to reduce the risk by obtaining a good surgical view, resulting in good hemostasis. The "elephant trunk technique" was used in anticipation of a staged descending aortic operation for residual dissecting aorta. We analyzed the surgical survival of patients with Stanford type A aortic dissection undergoing our operative procedure using hypothermic selective antegrade cerebral perfusion.

Methods: We performed our new technique in 27 patients (aged 61 ± 11 years, 15 male and 12 female patients, 22 patients with acute type A dissection, and 5 patients with chronic dissection).

Results: One in-hospital death (3.7% in total: 4.5% in acute dissection, 0% in chronic dissection) occurred in patients undergoing our new technique. Actuarial survival (including early death) was 91% at 5 years after the operation. One late death occurred as the result of a malignant tumor. Four patients underwent a staged reoperation for aneurysmal dilatation of the residual descending aorta or renal and splenic embolism as the result of thrombus from the false lumen 2 to 11 months (mean interval 6 months) after the initial operation. They have been doing well since the reoperation.

Conclusions: Our "distal anastomosis to the proximal level of the distal aortic arch" technique made aortic arch replacement easier and improved the survival of the arch replacement for aortic dissection, especially for acute type A dissection, by securing hemostasis in the suture line. Combining the elephant trunk technique with our new procedure is useful to perform a staged aortic replacement for dilatation and complication of the false lumen in the descending aorta.

From the First Department of Surgery, Gifu University School of Medicine, Gifu, Japan.

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Address for reprints: Yoshio Mori, MD, PhD, First Department of Surgery, Gifu University School of Medicine, 40 Tsukasa-machi, Gifu 500-8705, Japan (E-mail: moriyo@cc.gifu-u.ac.jp).

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In acute type A dissection, replacing the ascending and transverse aortic arch is recommended to reduce the risk of stroke and late complications related to the false lumen.[1] High mortality rates in patients with total arch replacement were seen in several reports.[2-4] In acute type A aortic dissection, the aortic wall is so fragile that reliable anastomosis with a good surgical view is important to secure good hemostasis. Since 1994, we have performed our new transverse aortic arch replacement in which the distal end of the graft is

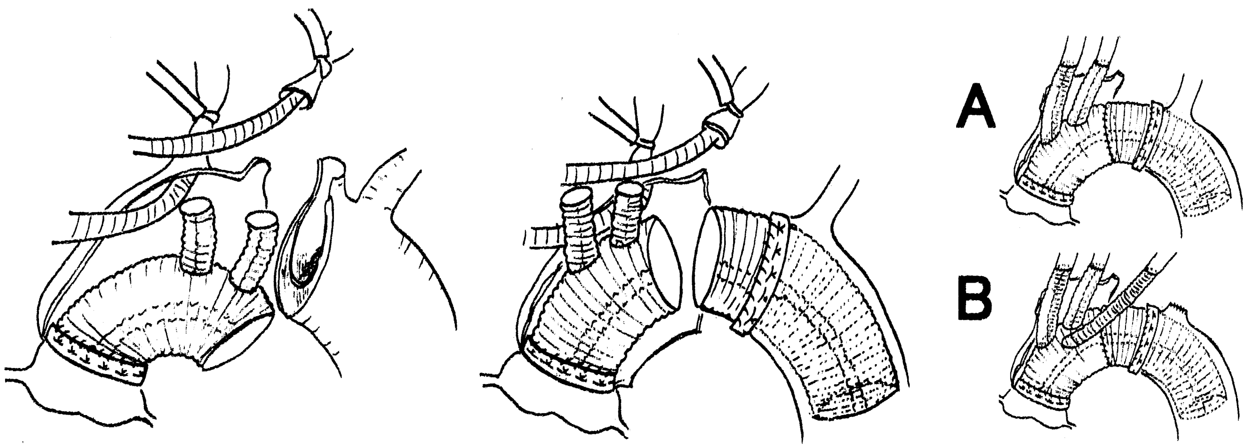

Figure 1. Distal anastomosis to the proximal level of the distal aortic arch technique. Distal end of the graft is anastomosed to the proximal site of the left subclavian artery take-off level of the distal arch. The elephant trunk is used in anticipation of a descending thoracic aortic operation. A, Side branches of the main graft were anastomosed to the brachiocephalic artery and the left common carotid artery in all patients. B, Subclavian artery was anastomosed to the side branch in 2 patients in our series.

anastomosed between the left common carotid artery and the left subclavian artery to reduce the risk by obtaining a good surgical view, resulting in good hemostasis. We analyzed the survival of patients with Stanford type A aortic dissection undergoing our operative procedure using hypothermic selective cerebral perfusion.

Patients and Methods

Operative Technique

Cardiopulmonary bypass was established by femoral artery and right atrial cannulation in all patients except 2, in whom arterial cannulation was inserted through the axillofemoral bypass graft (which was needed for acute femoral artery occlusion as the result of aortic dissection). The ascending aorta was clamped at the portion 3 cm proximal from the branched site of the brachiocephalic artery during core cooling. Myocardial protection was obtained with cold cardioplegic solution administered intermittently antegrade from the coronary ostia. The proximal end of the graft anastomosed to the Valsalva sinus was buttressed from both outside and inside the aortic wall with Teflon (DuPont, Wilmington, Del) (polytetrafluoroethylene) felt strips (Teflon sandwich technique) just above the level of the coronary ostia. This resulted in a resuspension of the native aortic valve even in patients with mild to moderate aortic valve insufficiency. In addition, felt strips adjusted the caliber of the stump of the aorta to acquire good coaptation of the aortic valve. Although 2 patients underwent aortic valve replacement or a modified Bentall operation for the chronic dissection associated with aortic regurgitation, aortic valve insufficiency was not observed in other patients. The patient was cooled to a rectal temperature of 20°C during proximal anastomosis. Retrograde femoral arterial perfusion was discontinued. Antegrade selective cerebral perfusion was established by the brachiocephalic artery, and left common carotid artery cannulation was established through the ostium of each branch from the inside of the aortic arch. The left subclavian artery was clamped. We used 2 pumps to perfuse the brachiocephalic artery and left common carotid artery separately to maintain a superficial temporal artery pressure of more than 50 mm Hg.[5] In our series, the perfusion rate ranged from 3.8 to 27.3 mL $\cdot$ min^{-1} $\cdot$ kg^{-1} (mean $\pm$ SD, 14.0 $\pm$ 5.0 mL $\cdot$ min^{-1} $\cdot$ kg^{-1}) in the brachiocephalic artery and from 0.4 to 13.4 mL $\cdot$ min^{-1} $\cdot$ kg^{-1} (5.5 $\pm$ 2.7 mL $\cdot$ min^{-1} $\cdot$ kg^{-1}) in the left common carotid artery. If we had no time to insert a catheter into the superficial temporal artery, we used the special connector that had a side arm for insertion of a small catheter (4F) to monitor the pressure of the common carotid artery.

Since 1994, we have performed our new transverse aortic arch replacement, in which the distal end of the graft is anastomosed between the left common carotid artery and the left subclavian artery to make distal anastomosis easier and to avoid recurrent nerve injury (Figure 1). A Teflon felt strip on the outside of the aortic wall was used to reinforce the anastomosis site. In this distal anastomosis, a modified elephant trunk insertion[6,7] was used in anticipation of the descending aortic operation for the residual dissected aorta. The length of the elephant trunk was 5 cm. The proximal graft was anastomosed to the distal graft with the elephant trunk. Antegrade perfusion restarted through the branch of the arch graft. Finally, branch grafts from the main graft were anastomosed to the brachiocephalic artery and the left common carotid artery. As shown in Figure 1, *A*, the left subclavian artery received blood supply through the space between the graft and aortic wall. As shown in Figure 1, *B*, the subclavian artery was anastomosed to the side branch in 2 patients whose left subclavian artery was exposed easily in our series. This procedure was undertaken for the patients with the primary tear in the (1) ascending aorta, when the distal end of the primary entry was located near the brachiocephalic artery in the ascending aorta, (2) transverse arch, and (3) descending aorta. We did not use this procedure in the patients who had no dissection in the aortic arch or in the patients

TABLE 1. Patient profile

Number of patients	27
Mean age (y)	61 ± 11
Sex (male:female)	15:12
Aortic valve dysfunction	
None	21 (78%)
Insufficiency	6 (22%)
Previous cardiac surgery	0
Duration between onset and operation	
Acute dissection	22 (81%)
Chronic dissection	5 (19%)
Location of primary tear	
Ascending aorta	13 (48%)
Transverse arch	7 (26%)
Descending aorta	7 (26%)
Acute myocardial infarction	0
Operation	
"Elephant trunk technique"	23 (85%)
Concurrent operation	
Aortic valve replacement	2 (7%)
Coronary artery bypass grafting	0
Abdominal aortic aneurysm repair	0
Extracorporeal circulation	
Cardiopulmonary bypass time (min)	239 ± 52
Selective cerebral perfusion time (min)	45 ± 16
Myocardial ischemic time (min)	110 ± 38
Operative mortality (<30 d)	
Acute dissection	0
Chronic dissection	0
In-hospital death (>31 d)	
Acute dissection	1 (3.7%)
Chronic dissection	0
Cause of operative and in-hospital death	
Bleeding	0
Acute myocardial infarction	0
MOF as the result of malperfusion	1 (3.7%)

MOF, Multiorgan failure.

whose intimal tear was located at the proximal part of the descending aorta just below the left subclavian artery. In these patients, the conventional procedure was used, in which the distal graft anastomosis is performed at the proximal descending aorta just distal to the origin of left subclavian artery.

Patients

Since 1994, we have performed our new technique in 27 patients (aged 61 ± 11 years, 15 male and 12 female patients, 22 patients with acute dissection, and 5 patients with chronic dissection). Table 1 shows the patient profile. The primary tear was in the ascending aorta in 48%, the transverse arch in 26%, and the descending aorta in 26%. The elephant trunk technique was performed in 23 patients (85%), and aortic root replacement with the composite graft was performed in 2 patients (7%). One patient (3.7%) had Marfan syndrome.

Results

One in-hospital death (3.7%) occurred in the patients undergoing our new procedure (Figure 1). One in-hospital death (4.5%) occurred in 22 patients with acute type A

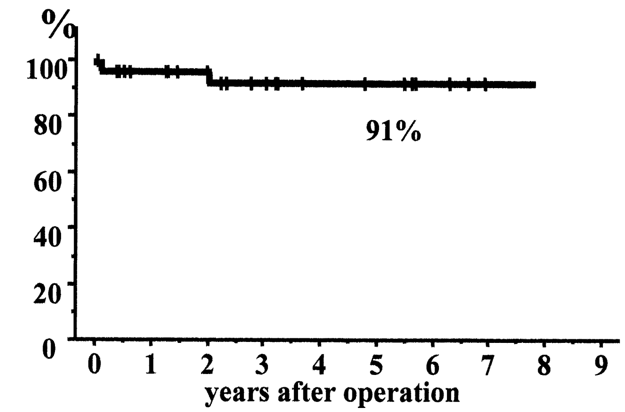

Figure 2. Actuarial survival, including in-hospital early death 5-year survival (%).

dissection. No in-hospital deaths occurred in 5 patients with chronic type A dissection. The in-hospital deaths in patients were the result of multiorgan failure caused by compromised visceral circulation as the result of preoperative cardiac tamponade and intraoperative malperfusion. During the same period, there were 9 patients who underwent conventional arch repair, because the intimal tear was located at the proximal part of the descending aorta just below the left subclavian artery. In those patients, extended replacement of the distal aorta was usually required distal to the tear in the descending aorta. There were 2 patients who died postoperatively (operative mortality rate 22%). During the same period, we performed ascending or hemiarch repair in 9 patients, because distal dissection was almost limited to the proximal arch. There were no in-hospital deaths in this group.

One patient (3.7%) had hoarseness as the result of recurrent nerve palsy. Two patients (7.4%) had brain complications perioperatively; they had had syncope episodes preoperatively at the onset of aortic dissection. These 2 patients demonstrated brachiocephalic artery stenosis as the result of dissection and thrombosis of the false lumen; 1 patient recovered completely without neurologic deficit, and 1 patient recovered with only paralysis of the left hand. Both patients are doing well so far.

The left radial arterial pulses were palpable in all patients with a nonreconstructed left subclavian artery; in the early postoperative period, we did not monitor the blood pressure of the left radial artery. In these patients, the systolic blood pressure ratio of the left arm and the right arm was 0.77 ± 0.16 in the late postoperative period. No patient had left vertebrobasilar artery insufficiency and claudication of the left arm postoperatively.

Patients were followed up from to 9 to 95 months, with a mean of 34 months. Figure 2 shows the actuarial survival by the Kaplan-Meier method. Actuarial survival (including early death) was 91% at 3 and 5 years after operation. There was 1 late death as the result of a malignant liver and lung tumor. Postoperative computed tomographic scans are usually completed in 6 to 12 months to determine the fate of the false lumen in patients with dilatation in the downstream aorta. Four patients required replacement of the descending aorta for aneurysmal dilatation or renal and splenic embolism as the result of thrombus from the false lumen 2 to 11 months (mean interval 6 months) after the initial operation. All patients underwent descending thoracic aortic graft replacement with reconstruction of the left subclavian artery through a left thoracotomy. They have been doing well since the reoperation.

Discussion

Although the ascending aorta is the most common site of the primary tear in patients with acute type A aortic dissection, the primary tear in the transverse arch occurs in 20% to 25% of these patients.[8,9] In 52% of the patients in our series, the primary tear occurred in the transverse arch or the descending aorta. In addition, even if the primary entry is in the ascending aorta, intraoperative aortic clamp injury or distal suture line of proximal portion of the ascending aorta might become another entry to the residual false lumen. Most patients with type A aortic dissection have a persistent false lumen after replacement of the ascending aorta.[10] There was a higher incidence of complication and reoperation in patients with a patent false lumen.[11] The replacement of the transverse aortic arch should be recommended to reduce the risk of stroke and late complications related to the false lumen. However, higher mortality was reported in patients with total arch replacement.[2-4] Transverse aortic arch repair is a technically demanding and time-consuming operation, especially for acute type A dissection. There are 2 ways to improve surgical results: (1) organ protection during arch repair and (2) an operative method to secure the anastomosis between the graft and dissected aorta.

Organ protection, especially brain protection, is important during the procedure. Profound hypothermia with circulatory arrest[12] and cerebral perfusion (antegrade[5] or retrograde[13]) have been major contributors to organ protection during surgery. Simple circulatory arrest or retrograde perfusion apparently has a time limitation for cerebral protection. Conversely, antegrade cerebral perfusion is believed to be most physiologic and to have the least time limitation. Antegrade selective cerebral perfusion enables us to perform the meticulous and time-consuming operation to manipulate the fragile dissected aortic wall. We use hypothermia and antegrade selective cerebral perfusion for brain protection, because our arch repair procedure takes longer than the safe time limits of circulatory arrest or retrograde cerebral perfusion. We determine the flow rate of selective cerebral perfusion to maintain the pressure of the superficial temporal artery or the common carotid artery above 50 mm Hg.[5] There were 2 patients with brain complications in our series. However, they had had syncope attacks preoperatively. It was believed that the brain complications resulted from suspicious cerebral hypoperfusion as the result of brachiocephalic stenosis caused by dissection or debris from a thrombus of the false lumen before initiation of selective cerebral perfusion during cardiopulmonary bypass. Fortunately, these patients recovered with minimum neurologic deficits and have been doing well.

Distal anastomosis at the descending aorta through a median sternotomy is so deep that hemostasis is difficult in the fragile acutely dissected aortic wall. Since 1994, we have performed our new arch replacement, in which the distal end of the graft is anastomosed between the left common carotid artery and the left subclavian artery to secure anastomosis with hemostasis of the distal anastomosis site. This procedure was undertaken for patients with the primary tear in the ascending aorta when the distal end of the primary entry was located near the brachiocephalic artery in the ascending aorta. Because it was not ideal that the distal end of the primary tear was involved with the suture line or distal to the distal anastomosis when only the ascending aorta was intended to be replaced for type A dissection, this procedure was undertaken for patients with the primary tear in the transverse arch. When the primary tear was in the descending aorta, this procedure was undertaken to prepare for anticipated reoperation for dilatation of the descending aorta.

Massive bleeding from the distal anastomosis site was not observed in patients undergoing this new distal anastomosis procedure. The mortality rate of patients in our series who underwent this new arch repair for acute type A dissection was 4.5%, which is lower than that of other reports of conventional transverse arch repair.[2-4] During the same period in our series, the operative mortality rate of patients who underwent conventional arch repair was 22%. However, it may not be meaningful to compare these 2 groups, because the patients' backgrounds differed, and the trial was not randomized.

Svensson and colleagues[14] reported on staged operations using elephant trunk anastomosis between the left carotid and subclavian arteries for true aneurysm of the distal aortic arch to reduce the tension on the suture line, because patients died in the interval between the first and second operations as the result of a rupture in the descending aorta.

Subsequent downstream aortic operation was undertaken in 4 patients after a mean interval of 6 months. Heinemann and colleagues[15] suggested a trunk extension of approximately 6 to 8 cm in length. They reported that a longer elephant trunk caused thrombus formation between the graft and the aortic wall. Their study included 14 patients in whom a descending aortic replacement using a proximal trunk was performed after a mean interval of 9.6 months (range, 1-58 months). In our series, all patients with reoperation underwent descending thoracic aortic graft replacement through the left thoracotomy approach. The elephant trunk (5 cm in length) sufficed for subsequent grafting, and all patients are doing well after surgery.

Conclusion

Our distal anastomosis to the proximal level of the distal aortic arch technique made aortic arch replacement easier and improved the survival of the arch replacement for aortic dissection, especially for acute type A dissection, by securing anastomosis with hemostasis in the suture line. Combining the elephant trunk technique with our procedure is necessary for patients undergoing staged aortic replacement for dilatation and complication of the false lumen.

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